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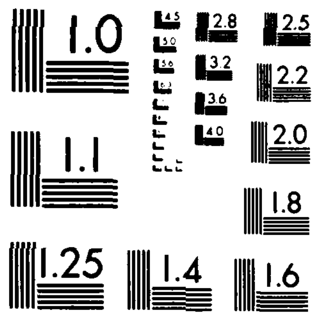

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SPACE-VARIANT OPTICAL SYSTEMS

Annual Technical Report

on

AFOSR

~~AFOSR Grant~~-79-0076

(Sept. 30, 1981 - Sept. 30, 1982)

by

John F. Walkup and Thomas F. Krile

Principal Investigators

November 1982

Optical Systems Laboratory

Department of Electrical Engineering

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Analytical and experimental investigations of 2-D space-variant optical processing techniques have been conducted. Coherent processing investigations have included (1) a continuing experimental study of the characteristics of UV-exposed photoresist phase masks for multiplex holography, and (2) both analytical and experimental studies of a technique for using wavelength-encoded tandem 1-D processors for performing 2-D processing. In the area of incoherent processing, we have completed an investigation of a tristimulus-based technique for performing complex operations using hue, saturation, and intensity para-

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ABSTRACT

Analytical and experimental investigations of 2-D space-variant optical processing techniques have been conducted. Coherent processing investigations have included (1) a continuing experimental study of the characteristics of UV-exposed photoresist phase masks for multiplex holography, and (2) both analytical and experimental studies of a technique for using wavelength-encoded tandem 1-D processors for performing 2-D processing. In the area of incoherent processing, we have completed an investigation of a tristimulus-based technique for performing complex operations using hue, saturation, and intensity parameters to represent complex numbers.

RESEARCH OBJECTIVES

During the funding period from September 30, 1981 to September 30, 1982, the major research objectives have been to analytically and experimentally investigate both coherent and incoherent optical processing techniques for performing two-dimensional (2-D) space-variant operations. In the coherent processing area, the major topics of investigation have been (1) the development of quality UV-exposed photoresist phase masks for use in multiplex holography, and (2) an analytical and experimental investigation of a white light technique employing tandem 1-D processors to perform 2-D space-variant operations. In the incoherent processing area, we have completed our proof-of-principle experiments to evaluate the tristimulus-based approach to the use of hue, saturation, and intensity as parameters to represent complex numbers and to perform the operations needed in a 2-D space-variant processor. Details are provided in the following sections.

SUMMARY OF RESULTS

(1) Random Phase Masks for Multiplex Holography

Phase masks for reference beam encoding are an essential element of space-variant processors using multiplex holography. During the past funding period, studies were continued to determine the exposure and development parameters necessary for accurate and repeatable surface contours in a photoresist medium. An argon-ion laser with UV mirrors was used as a source to provide controlled exposures of photoresist plates. Step-function test patterns were used to gather data on exposure times and development techniques versus phase depth. It was found that a simple Michelson interferometer did not have enough finesse to provide accurate phase change data, so a Varian A-scope interferometer was purchased. The A-scope, which is a multiple-beam interferometer utilizing a Fizeau plate, has been used to measure the resist thickness of the step-function test patterns. Now thickness tolerances of ± 130 Å can be measured accurately. This is well within the thickness tolerance of the photoresist coating needed to achieve the desired 180° phase shift in the mask. Tests have also shown that the development time of the photoresist does not affect the final resist thickness as extensively as originally thought.

The photoresist plates come with a chromium undercoating and, since this could affect the A-scope readings, a cross-check was made using a scanning electron microscope on the step-functions patterns. It was found that the reliability of the A-scope readings was not affected by the extra reflective layer on the photoresist plates.

The next step in the production of phase masks was to modify the

existing facility for directly "writing" computer generated functions on film so that it could be used at UV wavelengths. First, the acousto-optic shutter had to be replaced with a computer-controlled mechanical shutter because the acousto-optic modulator will not transmit UV. Then the beam-forming optics had to be redesigned to accomodate the new wavelengths. These modifications to the laser scanning facility have been completed, and faster scan exposure tests have been run using a UV sensitive film. The results are being analyzed to determine optimal pixel shapes and sizes to be used when constructing the phase masks on photoresist.

(2) <u>Tristimulus Incoherent Processor</u>

A system has been designed which exploits tristimulus color properties for representation and manipulation of complex numbers to produce the integral of a product of complex functions.[1] This system uses color television monitors and cameras to represent and operate on complex numbers in the 3-dimensional space defined by the National Standards for Color Television transmissions (the NTSC standards). These 3-dimensions also correspond to the intensity, hue, and saturation model of human vision. In this system, multiplication of numbers represented in polar form is done by controlling hue and saturation separately from intensity. The phase angles of the numbers to be multiplied are displayed as the saturations of two complementary hues for positive and negative phase angles. Then, the intensities are manipulated separately in a subtractive system to represent the multiplication of two complex number magnitudes.

The results of the multiplication are detected by a color television camera (phase angle) and a black-and-white camera (amplitude). A polar-

to-rectangular transformation is then done electronically on the output signals from the cameras. The transformed output is fed to the chrominance (hue and saturation) inputs of a color television monitor, keeping the intensity constant. The output of this monitor, now in complex rectangular form, is then summed by a collecting lens and the result is detected by another color television camera. Thus, since both operations of complex multiplication and addition can be done, the space-variant superposition integral may be evaluated.

A system has been set up to conduct proof-of-principle tests of this approach. Calibration and testing of the various system components was done to verify the linear models on which the tristimulus processor is based. Angle addition along a bipolar two-hue number line, represented by one of the signals of a color TV camera operating at constant intensity, was verified. The intensity of a simulated polar form product was obtained from the luminance signal of a black-and-white TV camera. An electronic polar-to-rectangular transform of the complex number represented by signals from the two cameras was successfully demonstrated. This signal was fed to a color monitor operating at a constant intensity level, where complex numbers are now represented in rectangular form by hue and saturation parameters. A lens was used to sum the rectangular form numbers onto a final color camera, whose output represents the sum of products of complex numbers, as desired. Thus the multiplication in polar form, electronic polar-to-rectangular conversion, and summation in rectangular form have all been individually verified by the test system. While noise and component nonlinearities still pose problems from a practical standpoint, the basic principles of tristimulus-based operations on complex numbers have been demonstrated.[2,3]

(3) 2-D Processing with Color-Encoded 1-D Processors

A major objective of this project has been to make use of the advantages of our earlier work on 1-D space-variant processors[4] in order to perform the more difficult task of 2-D space-variant processing. In performing a 2-D space-variant operation, the input is a 2-D function, and the kernal $h(x,y;\xi,\eta)$ is potentially a 4-D function. Therefore one difficulty in performing a 2-D superposition integral is making enough parameters available to handle such a kernal. Our approach to date has been to assume that $h(\cdot)$ is separable in Cartesian coordinates: i.e., that $h(x,y;\xi,\eta) = h_1(x,\xi)h_2(y,\eta)$. We have then used an achromatic coherent processor (i.e., a white light coherent processor), so that wavelength provides us with an additional parameter. The processor makes use of the dispersive properties of prisms, as well as an achromatic Fourier transformer, as part of its operation. To date we have completed a proof-of-principle experiment which verifies the validity of the approach. We are now looking at both refinements of this technique plus alternative techniques for performing 2-D space-variant processing with 1-D processors, as we believe that there may well exist a broad class of projective mapping techniques (the well known Radon transform being only one member of this class) which will permit us to perform these operations in real time. At the time of writing this report, an M.S. thesis[5] and one conference paper[6] have been completed. Another conference paper[7] and a journal article are planned.

References:

1. R. F. Carson, T. F. Krile, J. F. Walkup, "Tristimulus-Based Approach to Incoherent Optical Processing," J. Opt. Soc. Am., 71, 1594A, 1981 Annual Meeting, Optical Society of America, Kissimmee, Florida, October, 1981.

2. R. F. Carson, "Incoherent Optical Processing: A Tristimulus-Based Approach," M.S. thesis, Dept. of Electrical Engineering, Texas Tech University, August, 1982.

3. R. F. Carson, J. F. Walkup, T. F. Krile, "Incoherent Optical Processing: A Tristimulus-Based Method," (to be submitted to Applied Optics).

4. R. J. Marks II, J. F. Walkup, M. O. Hagler, T. F. Krile, "Space-Variant Processing of 1-D Signals," Appl. Optics, 16, 739-745 (1977).

5. J. M. Adams, "Space-Variant Two-Dimensional Processing Using Color-Encoded One-Dimensional Processors," M.S. thesis, Dept. of Electrical Engineering, Texas Tech University, December, 1982 (expected).

6. J. M. Adams, J. Shamir, T. F. Krile, J. F. Walkup, "Two-Dimensional Space-Variant Processing Using One-Dimensional Processors," Paper presented at the 1982 Annual Meeting, Optical Society of America, Tucson, AZ, October, 1982.

7. J. M. Adams, J. Shamir, T. F. Krile, J. F. Walkup, "2-D White-Light Space-Variant Processing," Paper to be presented at SPIE Los Angeles Technical Symposium, January, 1983.

RESEARCH PERSONNEL (1981-82)

1. Faculty

   Dr. J. F. Walkup, Co-Principal Investigator, Professor

   Dr. T. F. Krile, Co-Principal Investigator, Associate Professor

   Dr. J. Shamir, Research Associate, Visiting Associate Professor (Technion-Israel Institute of Technology)

2. Graduate Students

   B. H. Jones

   R. F. Carson

   J. M. Adams

   S. Chase

   A. Barsallo

3. Undergraduate Laboratory Assistants

   A. Barsallo

   F. Bermudez

   M. Metscher

COMPLETED THESES (1981-82)

1. B. H. Jones, "A Laser Plotter for Optical Processing," M.S. thesis, Dept. of Electrical Engineering, Texas Tech University, May, 1982.

2. R. F. Carson, "Incoherent Optical Processing: A Tristimulus-Based Approach," M.S. thesis, Dept. of Electrical Engineering, Texas Tech University, August, 1982.

RECORD OF JOURNAL PUBLICATIONS ON AFOSR-75-2855 and 79-0076

Journal Articles Published

1. L. M. Deen, J. F. Walkup and M. O. Hagler, "Respresentations of Space-Variant Optical Systems Using Volume Holograms," Appl. Optics, 14, 2438-2446 (1975).

2. R. J. Marks II, J. F. Walkup and M. O. Hagler, "A Sampling Theorem for Space-Variant Systems," J. Opt. Soc. Am., 66, 918-921 (1976).

3. R. J. Marks II, J. F. Walkup and M. O. Hagler, "Line Spread Function Notation," Appl. Optics, 15, 2289-2290 (1976).

4. R. J. Marks II, J. F. Walkup, M. O. Hagler, and T. F. Krile, "Space-Variant Processing of 1-D Signals," Appl. Optics, 16, 739-745 (1977).

5. R. J. Marks II, J. F. Walkup and T. F. Krile, "Ambiguity Function Display: An Improved Coherent Processor," Appl. Optics, 16, 746-750 (1977); addendum, 16, 1777 (1977).

6. T. F. Krile, R. J. Marks II, J. F. Walkup and M. O. Hagler, "Holographic Representations of Space-Variant Systems Using Phase-Coded Reference Beams," Appl. Optics, 16, 3131-3135 (1977).

7. R. J. Marks II, J. F. Walkup and M. O. Hagler, "Sampling Theorems for Linear, Shift-Variant Systems," *IEEE Trans. on Circuits and Systems*, CAS-25, 228-233 (1978).

8. R. J. Marks II and S. V. Bell, "Astigmatic Coherent Processor Analysis," Optical Engineering, 17, 167-169 (1978).

9. T. F. Krile, M. O. Hagler, W. D. Redus, and J. F. Walkup, "Multiplex Holography with Chirp-Modulated Binary Phase-Coded Reference Beam Masks," Appl. Optics, 18, 52-56 (1979).

10. R. J. Marks II, J. F. Walkup, and M. O. Hagler, "Methods of Linear System Characterication Through Response Cataloging," Appl. Optics, 18, 655-659 (1979).

11. R. J. Marks II, M. I. Jones, E. L. Kral, and J. F. Walkup, "One-Dimensional Linear Coherent Processing Using a Single Optical Element," Appl. Optics, 18, 2783-2786 (1979).

12. J. F. Walkup, "Novel Techniques for Optical Information Processing: An Introduction," 18, 2735-2736 (1979).

13. J. F. Walkup, "Space-Variant Coherent Optical Processing," Optical Engr., 19, 339-345 (1980).

14. M. O. Hagler, R. J. Marks II, E. L. Kral, J. F. Walkup, and T. F. Krile, "Scanning Technique for Coherent Processors," Appl. Optics, 19, 4253-4257 (1980).

15. R. Kasturi, T. F. Krile, and J. F. Walkup, "Multiplex Holography for Space-Variant Processing: A Transfer Function Sampling Approach," Appl. Optics, 20, 881-886 (1981).

16. C. A. Irby, M. O. Hagler, and T. F. Krile, "Multiplex Holograms: Digital Generation and Optical Retrieval," Appl. Optics, 21, 169-171 (1982).

17. E. L. Kral, J. F. Walkup, and M. O. Hagler, "Correlation Properties of Random Phase Diffusers for Multiplex Holography," Appl. Optics, 21, 1281-1290 (1982).

18. M. I. Jones, J. F. Walkup, and M. O. Hagler, "Multiplex Hologram Representations of Space-Variant Optical Systems Using Ground-Glass Encoded Reference Beams," Appl. Optics, 21, 1291-1297 (1982).

Journal Articles in Preparation

1. Incoherent Optical Processing: A Tristimulus-Based Method. (R. F. Carson, J. F. Walkup, T. F. Krile, to be submitted to Appl. Optics).

Scientific Reports

1. R. J. Marks II, "Space-Variant Coherent Optical Processing," Scientific Report AFOSR-75-2855-1, Optical Systems Laboratory, Department of Electrical Engineering, Texas Tech University, Lubbock, Texas, December 1, 1977.

2. M. I. Jones and E. L. Kral, "Multiplex Holography for Space-Variant Optical Processing," Scientific Report AFOSR-75-2855-2, Optical Systems Laboratory, Department of Electrical Engineering, Texas Tech University, Lubbock, Texas, September 1, 1979.

3. R. Kasturi, "Space-Variant Processing Using Phase Codes and Fourier-Plane Sampling Techniques," Scientific Report AFOSR-79-0076-1, Optical Systems Laboratory, Department of Electrical Engineering, Texas Tech University, Lubbock, Texas, June 1, 1980.

INTERACTION ACTIVITIES (1981-82)

A. Conference Papers Presented

1. R. F. Carson, J. F. Walkup, and T. F. Krile, "Tristimulus-Based Approach to Incoherent Optical Processing," J. Opt. Soc. Am., 71, 1594A, 1981 Annual Meeting, Optical Society of America, Kissimmee, Florida, October, 1981.

2. B. H. Jones, J. F. Walkup, and T. F. Krile, "Hybrid Laser Plotter for Optical Processing," J. Opt. Soc. Am., 71, 1595A, 1981 Annual Meeting, Optical Society of America, Kissimmee, Florida, October, 1981.

B. Other Activities

1. Presented seminars on research results obtained under AFOSR Grant 79-0076 (Optical Sciences Center, U. of Arizona; Jet Propulsion Lab - Caltech; Army Night Vision and Electro-Optics Laboratory) (J. F. Walkup).

2. Laboratory visits: Prof. H. H. Barrett (Arizona), Prof. A. A. Sawchuk (USC), Prof. E. Hansen (Dartmouth), Dr. R. Leighty (Army Engineering Topographic Labs), Prof. D. Psaltis (Caltech), NASA-Goddard. (J. F. Walkup/T. F. Krile).

3. Sabbatical leave with Prof. H. H. Barrett at Optical Sciences Center, U. Of Arizona. Research on techniques for performing 2-D space-variant processing with 1-D processors. (J. F. Walkup).

4. Attended 1982 Gordon Research Conference on Holography and Optical Information Processing in Plymouth, N.H., June 1982 (J. F. Walkup/ T. F. Krile).

5. Member of planning committee for the Second Workshop on Future Directions for Optical Information Processing. Attended planning meeting at AFOSR, Sept. 1982 (J. F. Walkup).

SUMMARY OF SIGNIFICANT ACCOMPLISHMENTS

1. Developed a computer-controlled exposure system for UV-exposed photoresist phase masks for multiplex holography.

2. Completed proof-of-principle experiments verifying the usefulness of a tristimulus-based incoherent processor using color TV cameras and monitors to perform incoherent space-variant processing.

3. Experiments essentially completed which verify our analytical work on a technique using color-encoded, tandem 1-D white light optical processors to perfrom 2-D space-variant processing

4. Initiated additional analytical work on other techniques for using 1-D optical processors to perform 2-D space-variant processing. Both incoherent and coherent processors are being considered.